Claims

[c1] A method to synthesize a robust controller to control a process of the type which may be modeled imperfectly, said method comprising:

a.providing an generalized plant model as in a prior-art D-K iteration method for synthesizing robust controllers, said generalized plant model comprising a nominal plant model, one or a plurality of selected perturbation weightings, one or a plurality of selected performance weightings, input ports for perturbation input, exogenous input, control input, and output ports for perturbation output, exogenous output, control output, said control input and said control output corresponding to a controller to be designed;

b.providing a convex closed-loop map by applying a parameterization method on said generalized plant model, said convex closed-loop map being convex in terms of a free controller design parameter; said convex closed-loop map having a plurality of input channels corresponding to the exogenous input and the perturbation output of said generalized plant model, said convex closed-loop map having a plurality of output channels corresponding to the exogenous output and the pertur-

bation input of said generalized plant model, said free controller design parameter being a stable system;
c.providing a means for optimizing a robust scaling for a robustness measure relating to said convex closed-loop map, while holding said free controller design parameter fixed, said robust scaling corresponding to the robust scaling of said prior-art D-K iteration method, said robustness measure corresponding to a robustness measure of said prior-art D-K iteration method;
d.computing said free controller design parameter by formulating a controller optimization problem while holding said robust scaling fixed, said controller optimization problem relating to said robustness measure and some other measure of said closed-loop map;
e.iterating step c and step d until a stopping criterion is satisfied.

[c2] 2.The method in claim 1 wherein the frequency response of said robust scaling is optimized on a set of selected frequencies, said convex control optimization problem formulates said robustness measure on a number of said set of selected frequencies, based on a selected frequency gridding.

[c3] 3.The method in claim 1 wherein said perturbation weighting is provided directly from a nonparametric estimate of the modeling uncertainty of said nominal plant

model on a finite number of selected frequencies.

[c4] 4.The method in claim 1 wherein said convex control optimization problem formulates said robustness measure on a set of selected frequencies based on frequency gridding, the decision variables of said controller optimization problem are the frequency response of said free controller design parameter on said set of selected frequencies, the inverse discrete Fourier transform of said frequency response is constrained to be periodically stable.

[c5] 5.The method in claim 1 wherein said convex control optimization problem formulates said robustness measure on a set of selected frequencies based on frequency gridding, the decision variables of said controller optimization problem are the coefficients of said free controller design parameter on said set of selected frequencies.

[c6] 6.The method in claim 1 wherein said controller optimization problem are changed during said iteration in step e.

[c7] 7.The method in claim 1 wherein said parameterization method relates to Youla-parameterization.

[c8] A method to synthesize a robust controller to control a

process of the type which may be modeled imperfectly, said method comprising:

a.providing an generalized plant model as in a prior-art D-K iteration method for synthesizing robust controllers, said generalized plant model comprising a nominal plant model, one or a plurality of selected perturbation weightings, one or a plurality of selected performance weightings, input ports for perturbation input, exogenous input, control input, and output ports for perturbation output, exogenous output, control output, said control input and said control output corresponding to a controller to be designed;

b.providing a convex closed-loop map by applying a parameterization method on said generalized plant model, said convex closed-loop map being convex in terms of afreecontroller design parameter; said convex closed-loop map having a plurality of input channels corresponding to the exogenous input and the perturbation output of said generalized plant model, said convex closed-loop map having a plurality of output channels corresponding to the exogenous output and the perturbation input of said generalized plant model, said free controller design parameter being a stable system;

c.providing a means for finding a robust scaling such that a robustness measure achieves a robustness level, said robust scaling corresponding to the robust scaling

of said prior-art D-K iteration method, said robustness measure corresponding to a robustness measure of said prior-art D-K iteration method;

d.computing said free controller design parameter by formulating a controller optimization problem while holding said robust scaling fixed, said control optimization problem relating to said robustness measure, said robustness level, and some other measure of said closed-loop map;

[c9] 9.The method in claim 8 wherein the frequency response of said robust scaling is optimized on a set of selected frequencies, said convex control optimization problem formulates said robustness measure on a number of said set of selected frequencies, based on a selected frequency gridding.

[c10] 10.The method in claim 8 wherein said perturbation weighting is provide directly from a nonparametric estimate of the modeling uncertainty of said nominal plant model on a finite number of selected frequencies.

[c11] 11.The method in claim 8 wherein said convex control optimization problem formulates said robustness measure on a set of selected frequencies based on frequency gridding, the decision variables of said controller optimization problem are the frequency response of said

free controller design parameter on said set of selected frequencies, the inverse discrete Fourier transform of said frequency response is constrained to be periodically stable.

[c12] 12.The method in claim 8 wherein said convex control optimization problem formulates said robustness measure on a set of selected frequencies based on frequency gridding, the decision variables of said controller optimization problem are the coefficients of said free controller design parameter on said set of selected frequencies.

[c13] 13.The method in claim 8 wherein said parameterization method relates to Youla-parameterization.

[c14] 14.The method in claim 8 wherein said means for finding said robust scaling involves with a direct search based on gridding of the parameter space of said robust scaling.

[c15] 15.The method in claim 8 wherein step c said means for finding said robust scaling comprises:
a.providing a means for optimizing a robust scaling for said robustness measure relating to said convex closed-loop map, while holding said free controller design parameter fixed;

b.computing said free controller design parameter by formulating a controller optimization problem while holding said robust scaling fixed, said controller optimization problem relating to said robustness measure;
c.iterating step a and step b until a stopping criterion is satisfied.

[c16] 16.The method in claim 8 wherein step d at least one input-output channel relating to said some other measure of said closed-loop map is included in said robustness measure;

[c17] 17.The method in claim 8 wherein step d all the input-output channels relating to said some other measure of said closed-loop map, and all the input-output channels of said robustness measure, are different.

[c18] 18.A method to synthesize a robust controller to control a process of the type which may be modeled imperfectly, said method comprising:
a.providing an generalized plant model as in a prior-art D-K iteration method for synthesizing robust controllers, said generalized plant model comprising a nominal plant model, one or a plurality of selected perturbation weightings, one or a plurality of selected performance weightings, input ports for perturbation input, exogenous input, control input, and output ports for perturba-

tion output, exogenous output, control output, said control input and said control output corresponding to a controller to be designed, said perturbation weighting is provide directly from a nonparametric estimate of the modeling uncertainty of said nominal plant model on a finite number of selected frequencies;

b.providing a convex closed-loop map by applying a parameterization method on said generalized plant model, said convex closed-loop map being convex in terms of a free controller design parameter; said convex closed-loop map having a plurality of input channels corresponding to the exogenous input and the perturbation output of said generalized plant model, said convex closed-loop map having a plurality of output channels corresponding to the exogenous output and the perturbation input of said generalized plant model, said free controller design parameter being a stable system;

c.providing a means for optimizing a robust scaling for a robustness measure relating to said convex closed-loop map, while holding said free controller design parameter fixed, said robust scaling corresponding to the robust scaling of said prior-art D-K iteration method, said robustness measure corresponding to a robustness measure of said prior-art D-K iteration method;

d.computing said free controller design parameter by formulating a controller optimization problem while

holding said robust scaling fixed, said controller optimization problem relating to said robustness measure;
e.iterating step c and step d until a stopping criterion is satisfied.

[c19] 19.A method to synthesize a robust controller to control a process of the type which may be modeled imperfectly, said method comprising:
a.providing an generalized plant model as in aprior-art D-K iteration method for synthesizing robust controllers, said generalized plant model comprising a nominal plant model, one or a plurality of selected perturbation weightings, one or a plurality of selected performance weightings, input ports for perturbation input, exogenous input, control input, and output ports for perturbation output, exogenous output, control output, said control input and said control output corresponding to a controller to be designed;
b.providing a convex closed-loop map by applying a parameterization method on said generalized plant model, said convex closed-loop map being convex in terms of a free controller design parameter; said convex closed-loop map having a plurality of input channels corresponding to the exogenous input and the perturbation output of said generalized plant model, said convex closed-loop map having a plurality of output channels

corresponding to the exogenous output and the perturbation input of said generalized plant model, said free controller design parameter being a stable system;
c.providing a means for optimizing a robust scaling for a robustness measure relating to said convex closed-loop map, while holding said free controller design parameter fixed, said robust scaling corresponding to the robust scaling of said prior-art D-K iteration method, said robustness measure corresponding to a robustness measure of said prior-art D-K iteration method;
d.computing said free controller design parameter by formulating a controller optimization problem while holding said robust scaling fixed, said controller optimization problem relating to said robustness measure, said convex control optimization problem formulates said robustness measure on a set of selected frequencies based on frequency gridding, the decision variables of said controller optimization problem are the frequency response of said free controller design parameter on said set of selected frequencies, the inverse discrete Fourier transform of said frequency response is constrained to be periodically stable;
e.iterating step c and step d until a stopping criterion is satisfied.